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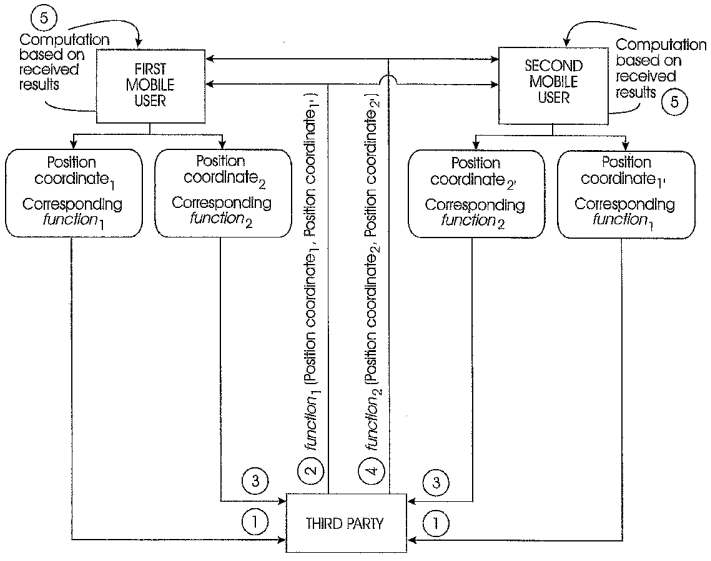

(57) Abstract: Described is a way for computing proximity (location-based proximity or preference-based proximity) between mobile wireless subscribers (who use different services) without either divulging their location/preference to the other (preservation of privacy). Privacy is kept by providing location/preference information in steps, along with an evaluation function. The services receive partial results and then locally compute the final result, or proximity. The term proximity includes not just physical proximity but also multi-dimensional data such as preference profiles and vectors (e.g., an affinity for baseball, apple pie, and ballroom dancing.).

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METHOD, PROGRAMM AND SERVICE FOR ANONYMOUSLY TESTING LOCATION BASED FOR PREFERENCE BASED PROXOMITY BETWEEN MOBILE SUBSCRIBERS BY SEPERATE TRANSFER AND EVALUATION OF PARAMETERS

BACKGROUND OF THE INVENTION

Field of Invention

The present invention relates generally to the field of mobile communication devices. More specifically, the present invention is related to anonymously testing proximity between mobile users without revealing individual phase space coordinates.

Discussion of Prior Art

Application Service Providers (ASP's) are increasingly offering a myriad of services over various networks. Many of these services make use of a user's location data to provide targeted user-specific information.

A specific implementation of such a service is a location-based service that requires detecting and reporting the relative proximity of two or more users. There exists a multitude of Wireless Service Providers (WSPs) that are able to deliver Location Tracking Services (LTSs) (or they may allow users to subscribe to a multitude of such LTSs). Since individuals may wish or need to be aware of their proximity to users subscribing to different service providers, information must be exchanged between the different service providers to detect proximity. Exchanging an individual's location data is undesirable, as it exposes the user to potential threats with regard to his/her privacy. By the same token, not exchanging the data severely diminishes the utility of such location-based services.

A brief description of prior art in the area of location-based services is provided below, but it should be noted that the prior art fail to provide for a system or method to anonymously test for the proximity of users without exchanging their location coordinates.

A prior art solution concerning the exchange of a user's location data involves encrypting the location data and sharing such encrypted data between the wireless service providers. This solution, however, has some major disadvantages, some of which are outlined below:

1) Management of the public key encryption is complex - especially given the rate of queries and proximity calculations required. An individual wireless provider may have millions of clients, and each of

these clients may wish to be alerted to the proximity of users of dozens of other wireless services.

2) Assuming the wireless providers exchange the information protected by encryptions, at some point the other service providers will be in possession of the location data for non-subscribing users. This requires that users trust every wireless provider (whether they are subscribers or not) to control access to this data. The system and method of the present invention eliminates this problem by avoiding the sharing of sensitive data.

The published patent application to Doi et al. (US 2001/0014911 A1) provides for a method and system for providing services wherein a trusted service provider provides service information dependent on location information of a mobile terminal to the mobile terminal in response to a service request with the location information sent by the mobile terminal. Doi et al., however, fail to address privacy concerns in the communication between multiple instances of such services.

The published patent application to Kinnunen et al. (US 2001/0018349 A1) provides for location-dependent services. Disclosed is a location-based system (LBS) for providing location-dependent services to a plurality of mobile terminals within a coverage area.

The published patent application to Watson (US 2002/0026517 A1) enables communications of electronic data between an information requestor and a geographically proximate service provider. Disclosed is a method for transferring electronic data comprising: receiving a request to access a communications system at a first geographical location from a client located at a second geographical remote from the first geographical location; identifying a proxy local to the client in the second geographical location; and receiving subsequent data requests from the client at the proxy. Watson, however, fails to disclose a third-party anonymous function evaluation service. Additionally, Watson requires trust and knowledge between the service providers.

The PCT publication to Huber et al. (WO 0079811 A2) provides for a method and system for offering mobile subscribers anonymous, location-based services. Disclosed is a method wherein a user, who has his/her own trusted service provider, picks one or more services he/she is interested in and sends his/her location to the trusted service provider, whereupon the service provider gets the location of the service and

performs a range query. Thus, the service provider researches locations for services (for example, the yellow pages). The PCT publication to Lammi et al. (WO 0128273 A1) provides for a similar recitation.

The published patent application to Hunzinger (US 2002/001173 A1) provides for communication of location information in a wireless communication system. Disclosed is a mobile station, such as a cellular or PCS phone, in a wireless communication system which transmits position information to the system server. The mobile station may communicate position location and movement tracking information between the mobile station and the wireless communication infrastructure.

The U.S. patent to Drane et al. (U.S. 6,275,705) provides for a location tracking system. The method allows for finding the position of a mobile radio-frequency transceiver in a communications system. Determination includes the means to use the known distances and measured times to determine the relative time offsets of transmissions from each base station and location means to use the determined relative time offsets and to calculate the position of a mobile transceiver in the network area using hyperbolic positioning techniques.

The PCT publication to Natarajan et al. (WO 01/65339) provides for an architecture for providing information to devices wherein the architecture comprises a data collector, an information server, an evaluation mechanism, and an action handler. The evaluation mechanism determines if a change occurs in an evaluation of an expression and generates a notification.

The non-patent literature to Herzberg et al. entitled "On Traveling Incognito" discusses solutions to anonymity in mobile environments. A "frequently changing" aliasing is provided as part of the solution.

Whatever the precise merits, features, and advantages of the above-cited prior art, none of them achieves or fulfills the purposes of the present invention.

SUMMARY OF THE INVENTION

In a first aspect of the invention there is provided a method for assisting a first and second tracking service in anonymizing preference data associated with a first and second user in a phase space, said first and second tracking service tracking preferences of said first and second

user respectively, said preference data being defined by one or more parameters, said method comprising the steps of:

a. receiving a request for function evaluation from each tracking service, said request identifying a parameter to be transmitted and a corresponding function to be used for evaluating said identified parameter;

b. transmitting a confirmation to each tracking service indicating transmission of said identified parameter is expected;

c. receiving said identified parameter from each tracking service;

d. evaluating said corresponding function based on said received parameter from each tracking service;

e. transmitting said evaluated result to each tracking service; and wherein steps a through e are repeated for each additional parameter required to define preference data and corresponding function such that each of said service's receives function evaluated results for each parameter separately and utilizes such evaluated results to locally estimate proximity between said first and second user in said phase space without revealing their preference data.

In a second aspect of the invention there is provided an article of manufacture comprising a computer usable medium having computer readable program code embodied therein for assisting a first and second tracking service in anonymizing preference data associated with a first and second user in a phase space, said first and second tracking service tracking preferences of said first and second user respectively, said preference data being defined by one or more parameters, said method comprising the steps of:

a. computer readable program code aiding in receiving a request for function evaluation from each tracking service, said request identifying a parameter to be transmitted and a corresponding function to be used for evaluating said identified parameter;

b. computer readable program code aiding in transmitting a confirmation to each tracking service indicating transmission of said identified parameter is expected;

c. computer readable program code aiding in receiving said identified parameter from each tracking service;

d. computer readable program code evaluating said corresponding function based on said received parameter from each tracking service;

e. computer readable program code aiding in transmitting said evaluated result to each tracking service; and

wherein computer readable program code of steps a through e are repeated for each additional parameter required to define preference data and corresponding function such that each of said service's receives function evaluated results for each parameter separately and utilizes such evaluated results to locally estimate proximity between said first and second user in said phase space without revealing their preference data.

In a third aspect of the invention there is provided a method for anonymous proximity detection between a first and second mobile user, said first and second mobile users being tracked by a first and second location tracking service (LTS) respectively, said method as implemented by each LTS comprising the steps of:

a. transmitting, to a third party, a first location coordinate along with a corresponding first function to evaluate;

b. receiving a first result from said third party, said first result based upon an evaluation of said first function with said first location coordinate;

c. transmitting, to said third party, a second location coordinate along with a second corresponding function to evaluate;

d. receiving a second result from said third party, said second result based upon an evaluation of second function with said second location coordinate; and

e. computing a measure of distance based upon said received first and second results, said computed distance providing each user with an indication of proximity with respect to the other user.

In a fourth aspect of the invention there is an anonymous function evaluation service (AFES) comprising:

a. an interface communicating with various tracking services or wireless service providers (WSPs) and receiving parameters and corresponding functions, said parameters associated with one or more users;

b. a task list storing said functions to be evaluated on received data;

c. a data cache storing said received parameters to be processed;

d. a function evaluation engine evaluating mathematical function(s) on parameters; and

e. a task manager operatively linked with said task list, data cache, and function evaluation engine, said task manager: (i) receiving parameters and corresponding functions from said interface; (ii) sending said functions and parameters to task list and data cache respectively; (iii) retrieving said functions from data cache; and (iv) communicating with function evaluation engine and sending results of said function evaluation engine back to said interface for forwarding values to requesting services.

In a specific embodiment there is provided for a system and a method for anonymizing data associated with mobile telephone users in a phase space, wherein such data is used in the calculating proximity between the users without divulging their location or preference vectors in the phase space. The privacy is kept by providing location coordinate information or preference vector coordinate information in steps, along with an evaluation function. The services receive the partial results and then locally compute the final result, giving a proximity estimate. It should be noted that the term proximity includes not just proximity in terms of Euclidean distance but includes proximity in a phase space made of preference profiles and vectors (e.g., affinity for baseball, apple pie, ballroom dancing, etc.).

In a specific embodiment, the present invention's method assists a first and second location tracking service (LTS) in anonymizing location data associated with a first and second user in a phase space, wherein the first and second user are tracked by the first and second LTS respectively. The location data is defined by one or more parameters. The method, as implemented in an anonymous function evaluation service (AFES), comprises the following steps: (1) receiving a request for function evaluation from each LTS, wherein the request identifies a

parameter to be transmitted and a corresponding function to be used for evaluating said identified parameter; (2) transmitting a confirmation to each LTS indicating the AFES is awaiting reception of the identified parameter; (c) receiving the identified parameter from each LTS; (3) evaluating the corresponding function based on the received parameter from each LTS; and (4) transmitting the evaluated result to each LTS. Steps a-e are repeated for each additional parameter required to define location data and corresponding function such that each of said LTS's receives function evaluated results from said AFES for each parameter separately and utilizes such evaluated results to locally estimate proximity between said first and second user in said phase space without revealing their location data.

The anonymous function evaluation service (AFES) comprises: (1) an interface to communicate with various location tracking services (LTSs) or wireless service providers (WSPs) and receive parameters and corresponding functions; (2) a task list storing the functions to be evaluated on received data; (3) a data cache storing the received parameters to be processed; (4) a function evaluation engine evaluating mathematical function(s) on parameters; and (5) a task manager operatively linked with the task list, data cache, and function evaluation engine, said task manager: receiving parameters and corresponding functions from the interface; sending the functions and parameters to task list and data cache respectively; retrieving said functions from data cache; and communicating with function evaluation engine and sending results of the function evaluation engine back to the interface for forwarding values to requesting services.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 illustrates a scenario wherein a set of preferences associated with an individual is represented using a vector V={pref_1, pref_2, …, pref_n}.

Figure 2 illustrates an exemplary embodiment of the present invention's method for estimating proximity between two mobile users.

Figure 3 illustrates a specific example of the present invention's architecture for anonymizing location data.

Figure 4 provides a detailed architecture of the anonymous function evaluation service (AFES) of Figure 3.

Figure 5 illustrates subcomponents associated with the location tracking service (LTS).

Figure 6 illustrates a time-line diagram representative of a specific example outlining the various interactions of the components (location tracking service A, location service tracking B, and the anonymous function evaluation service) of the present invention's architecture shown in Figure 3.

Figure 7 illustrates a flowchart outlining the process associated with the location receiver.

Figure 8 illustrates a flow diagram of the request handler process.

Figure 9 illustrates a flow diagram outlining the functionality of the AFES.

Figure 10 summarizes a flow diagram outlining the various interactions between a third party (AFES) and users A and B for the specific example of calculating proximity based upon a calculation of the Euclidean distance between A and B.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

While this invention is illustrated and described in a preferred embodiment, the invention may be produced in many different configurations. There is depicted in the drawings, and will herein be described in detail, a preferred embodiment of the invention, with the understanding that the present disclosure is to be considered an exemplification of the principles of the invention and the associated functional specifications for its construction and is not intended to limit the invention to the embodiment illustrated. Those skilled in the art will envision many other possible variations within the scope of the present invention.

It should be noted that the term "distance" as used throughout the specification includes not just physical proximity, but also includes multi-dimensional data such as preference profiles and vectors (e.g., an affinity for baseball, apple pie, ball room dancing, etc.). Hence, the literal interpretation of the term "distance" should not be used to limit the scope of the present invention.

The present embodiment provides for a system and method to estimate proximity in an arbitrary phase space without exchanging specific preference data. A generalized example would include proximity estimation in a phase space defined by *n* dimensional preference vectors. Figure 1 illustrates such a scenario, wherein a person's preferences can be represented using orthogonal personal preference components. A set of preferences associated with an individual is represented using a vector V={pref_1, pref_2, …, pref_n}, wherein pref_i is a scalar measure of a person's like or dislike for some specific property. One can measure the difference between the profile vectors of two people in exactly the same way one measures the distance in space by sending the orthogonal scalar measures one property at a time. Proximity between two individuals in this phase space is the difference between the preference vectors associated with each of the individuals. For example, if user A has a preference vector of V_1={pref_1, pref_2, …, pref_n}, and user B has a preference vector V_2={pref_1',pref_2', …, pref_n'}, then the proximity is given by $|V_2-V_1|$.

Figure 2 illustrates an exemplary embodiment of the present invention's method for estimating proximity between two mobile users. In the method in Figure 2, coordinates in a particular phase space and associated functions are sent individually to a third party. The third party calculates a parameter for each of the received functions and coordinates and separately forwards each of the estimated parameters to each of the users. Based upon the received parameters, users are able to perform various computations locally to estimate proximity to other users. For example, a local computation for distance between two users in a particular multidimensional phase space can be made wherein the phase space is defined by specific preference profiles and vectors (e.g., an affinity for baseball, apple pie, and ballroom dancing).

Figure 3 illustrates a specific example of the present invention's architecture **300** for anonymizing location data. Architecture **300** comprises: location tracking service A **302**, location tracking service B **304**, and anonymous function evaluation service (AFES) **306**. Both location tracking service A **302** and B **304** are able to track one or more clients, wherein the location tracking service (LTS) could be provided by a wireless service providers (WSP) or by an independent service provider. A description of each of the components of architecture **300** is provided below:

1. AFES **306**: The present embodiments third-party Anonymous Function Evaluation Service (AFES) receives collections of anonymized floating point values; and by design, it is never able to determine the location of any user of any service. Therefore, the AFES cannot be corrupted or otherwise compromise the privacy of users of any wireless service. The AFES simply receives numerical data from the individual wireless services and performs function evaluation on that data based on the instructions of the respective wireless services. It responds to the (registered) requesting services with the results of these calculations on the data they submitted (in coordination with other LTSs). Hence, the AFES never knows the location of any user. The wireless services are aware of their own user's locations and can deduce the proximity of their users to subscribers of other wireless service providers, but need never share their user locations with other service providers. Figure 4 provides a detailed architecture of the AFES **306** of Figure 3. AFES interacts with a multitude of WSPs or LTSs (**402**, **404**, **406**) over a protocol such as hypertext transfer protocol (HTTP). AFES **306** receives numerical data and instructions for function evaluation and returns the results of function evaluations. Subcomponents of the AFES **306** include:

a B-B interface **408**: This subcomponent handles communication (via protocols such as HTTP) with various LTSs or other WSPs. B-B interface **408** receives collections, enumerations, or vectors of floating point values. B-B interface **408** also receives collections of identifying keys for enumerated values and functions to allow collections from separated tracking services to be evaluated together.

b. Task List **410**: Subcomponent **410** stores a list of tasks and functions to be evaluated on data.

c. Data Cache **412**: Subcomponent **412** stores collections or enumerations of data (floating point numbers) to be processed.

d. Task Manager **414**: Subcomponent **414** manages the AFES architecture **306**. Such management includes: (1) receiving enumerations from B-B interface **408**; (2) sending enumerated values to task list **410** and data cache **412**; (3) retrieving data and evaluation functions from data cache **412**; (4) handling communications with function evaluation engine **416**; (5) performing validity checks on data, evaluation functions, and identifying keys; (6) catching errors; and (7) sending results of function evaluation

engine **416** back to B-B interface **408** for forwarding values to requesting services.

e. Function Evaluation Engine **416**: Subcomponent **416** evaluates mathematical function(s) on floating point or other data (individually or as a collection, enumeration, or vector).

2. Location Tracking Service (LTS) **302** and **304**: A wireless service provider in communication with a multitude of clients through cellular or other wireless network(s). Figure 5 illustrates subcomponents associated with the LTS **302** and **304**. A brief description of these subcomponents are provided below:

a. Client Profile Database **502**: Subcomponent **502** contains client ID's, billing information, location service profile (what services the client uses), etc.

b. Proximity Alert Database **504**: Each client ID specifies what other clients (or groups or events) they wish to receive alerts about. Each alert entry specifies (if necessary) the URL or ID of foreign location service providers (if not part of the current LTS system).

c. System Manager **506**: Controls access to the client profile and proximity databases in response to requests from the B-B interface **510**. System manager **506** manages client data through the client interface **508**.

d. Client Interface **508**: Subcomponent **508** communicates with client devices over a network such as a cellular network. Client interface **508** receives location data from client devices and sends that data to the system manager **506**.

e. B-B interface **510**: Subcomponent **510** comprises a firewall for monitoring activity over the World Wide Web (WWW). The B-B interface **510** passes requests from other LTS providers to the system manager **506** and sends requests to other LTS providers. Additionally, subcomponent **510** handles communications with the AFES service(s).

3. Wireless Service Provider.

4. Client: User of a client device.

5. Client device: Wireless devices with native tracking (e.g., GPS).

Alternatively, the device may be tracked by an LTS provider by the communication or cellular hub the device is in communication with.

Figure 6 illustrates a time-line diagram representative of a specific example outlining the various interactions of the components (location tracking service A, location service tracking B, and the anonymous function evaluation service) of the present invention's architecture shown in Figure

It should be understood that the example is provided merely for the purposes of outlining the functionality associated with the components of the architecture of Figure 3. Hence, the implementation of the present invention should not be restricted to just examples mentioned in the specification.

The example outlined in Figure 6 is directed to alerting a user, *i*, if another user, *j*, is in a proximate region. The steps shown in the time-line diagram are given below:

Step **608**: A request for the range between users *i* and *j* is exchanged between location tracking service A **602** and location service B **604**.

Step **610**: In this step, a confirmation is exchanged between location tracking services A **602** and B **604** regarding which parameter is to be first transmitted to AFES. In the specific example shown, the transmission of the *x* coordinate (as the first coordinate to be transmitted) is confirmed as the parameter to be transmitted first.

Step **612**: In this step, an identification is made (by location tracking service A **602** and B **604**) with regard to what common function(s) is to be used for evaluation by AFES **606**. In the specific example, AFES **606** is told to expect parameter $._i$ and is expected to return the evaluated function $(._i-._j)^2$ back to location tracking service A **602** and B **604**.

Step **614**: A confirmation is sent from AFES **606** to each of the location tracking services A **602** and B **604** regarding the agreed upon function.

Step **616**: In this step, as decided upon in step **610**, a first parameter is sent from location tracking service A **602** to AFES **606**. In the specific example, parameter x_i is sent from location tracking service A **602** to AFES **606** and, similarly, parameter x_j is sent from location tracking service B **604** to AFES **606**.

Step **618**: In this step, based upon the agreed upon function, a new parameter is calculated based upon the function and forwarded to location tracking services A **602** and B **604**. In the specific example, the agreed upon function is $(._i-._j)^2$, and the result $)x^2 = (x_i - x_j)^2$ is transmitted to location tracking services A **602** and B **604**.

Step **620**: In this step, similar to step **612**, an identification is made (by location tracking service A **602** and B **604**) with regard to what common function(s) is to be used for evaluation by AFES **606** for the next parameter to be passed. In the specific example, AFES **606** is told to expect another input parameter $._i$ and, in turn, is expected to return the evaluated function $(._i-._j)^2$ back to location tracking service A **602** and B **604**.

Step **622**: This step is similar to the confirmation step **614**.

Step **624**: This step is similar to step **616**, wherein a new parameters y_i and y_j are sent to the AFES **606** by location tracking services A **602** and B **604**, respectively.

Step **626**: In this step, based upon the agreed upon function, a new parameter is calculated based upon the function and forwarded to location tracking services A **602** and B **604**. In the specific example, the agreed upon function is $(._i-._j)^2$ and the result $)y^2 = (y_i - y_j)^2$ is transmitted to location tracking services A **602** and B **604**.

Lastly, a computation is made locally for calculating the distance based upon the received values $)x^2$ and $)y^2$. Thus, distance R is calculated using $[()x^2)+()y^2)]^{1/2}$. After R is computed, an evaluation condition is assessed. For example, as an estimate of proximity, computed R can be compared to a threshold R^* (i.e., is $R < R^*$?). If the evaluation condition is met (if it is true that $R < R^*$), an alert is issued.

Figures 7-9 collectively illustrate the methods associated with each of the entities in the architecture of Figure 3. Figure 7 illustrates a

flowchart **700** outlining the process associated with the location receiver. In step **705**, a location update is received from user A. Next, in step **710**, an evaluation is made if user A has moved. If user A has not moved, then step **705** is repeated. On the other hand, if user A has moved, in step **715** a range request is sent to the wireless service provider (WSP) of user B. In step **725**, AFES is notified to expect data; in step **730**, coordinate x_n is sent to AFES. In step **735**, a result equal to the difference squared is received. In step **740**, an evaluation is made if there are more coordinates are to be sent and, if so, steps **725** through **740** are repeated for each coordinate. On the other hand, if no more coordinates are to be sent, the distance calculation is performed to detect the proximity to user B. Lastly, after the proximity calculation in step **745** is completed, steps **705** through **745** can be repeated to dynamically update proximity information.

Figure 8 illustrates a flow diagram **800** of the request handler process. In step **805**, a range request is received from wireless service provider (WSP) of user A; and in step **810**, a notification is sent to AFES to expect data. In step **815**, coordinate x_n is sent to AFES; in step **820**, the distance-squared parameter is received. In step **825**, an evaluation is made if more coordinates are to be sent and, if so, steps **810** through **825** are repeated. On the other hand, if there are no more coordinates to send, a proximity calculation is initiated to detect the proximity to user A. After the proximity calculation in step **830**, steps **805** through **830** are repeated to dynamically update proximity information.

Figure 9 illustrates a flow diagram **900** outlining the functionality of the AFES. In step **905**, the AFES receives a function evaluation request; in step **910**, values from the wireless service provider of user U_1 are received. Next, in step **915**, an evaluation is made if more data is to be received from wireless service providers. If so, steps **910** through **915** are repeated. On the other hand, if there is no more data to be received, a function is computed and returned to all appropriate wireless service providers.

Figure 10 summarizes a flow diagram outlining the various interactions between a third party (AFES) **1002** and users A **1004** and B **1006** for the specific example of calculating proximity based on a calculation of the Euclidean distance between A and B. In this specific example, the x coordinates (x_1 **1008** and x_2 **1010**) and the y coordinates (y_1 **1012**and y_2 **1014**) are independently sent to the third party **1002**, along with

corresponding function(s) ($function_1$ **1016** and $function_2$ **1018**). In this example, given x_1 and x_2, $function_1$ is calculated based upon $R_1=function_1(x_1,x_2)=|x_1-x_2|^2$. Similarly, given y_1 and y_2, $function_1$ is calculated based upon $R_2=function_2(y_1,y_2)=|y_1-y_2|^2$. The results, R_1 and R_2, are calculated based upon the identified evaluation functions and forwarded separately to each of the users (A **1004** and B **1006**). Each user is then able to compute the proximity locally.

It should be noted that the anonymous function evaluation can be accomplished with significantly less communication and confirmation overhead. The two services would periodically exchange lists of users (IDs) for whom they wish to estimate proximity. The AFS would be told to expect a collection of floating point numbers from each service and would compute the requested function evaluation on each of these collections (returning a collection of answers). The randomization of x, y, and z coordinates for users within these collections would also be determined in one communication step between the wireless providers.

As an example, cell phones of users A and B can be equipped with an embedded java virtual machine such that arbitrary code can be executed locally to compute proximity. It should, however, be noted that mobile devices can be equipped with means for implementing code in other higher-level languages, such as C, C++, and the type of language used should not be used to limit the present invention. In the specific example of Figure 10, given R1 and R2, users A and B are able to locally calculate the Euclidean distance based upon: Distance=$R=(R_1+R_2)^{1/2}$. This result is locally compared against a pre-determined threshold, t, and if estimated value, R, is within the threshold, t, an alert is issued to A or B.

Furthermore, the present invention includes a computer program code-based product, which is a storage medium having program code stored therein which can be used to instruct a computer to perform any of the methods associated with the present invention. The computer storage medium includes any of, but is not limited to, the following: CD-ROM, DVD, magnetic tape, optical disc, hard drive, floppy disk, ferroelectric memory, flash memory, ferromagnetic memory, optical storage, charge coupled devices, magnetic or optical cards, smart cards, EEPROM, EPROM, RAM, ROM, DRAM, SRAM, SDRAM, or any other appropriate static or dynamic memory or data storage devices.

Implemented in computer program code based products are software modules for assisting a first and second tracking service in anonymizing preference data associated with a first and second user in a phase space (wherein the first and second tracking service track the location of the first and second user respectively and the preference data is defined by one or more parameters). The software modules: (1) aid in the reception of a request for function evaluation from each tracking service, wherein the request identifies a parameter to be transmitted and a corresponding function to be used for evaluating the identified parameter; (2) aid in the transmission of a confirmation to each tracking service indicating that the AFES is awaiting reception of the identified parameter; (3) aid in the reception of the identified parameter from each tracking service; (4) evaluate the corresponding function based on the received parameter from each tracking service; and (5) aid in the transmission of the evaluated result to each tracking service.

CONCLUSION

A system and method has been shown in the above embodiments for the effective implementation of a system and method to anonymously test for proximity of mobile users without revealing individual phase space coordinates. While various preferred embodiments have been shown and described, it will be understood that there is no intent to limit the invention by such disclosure, but rather, it is intended to cover all modifications and alternate constructions falling within the spirit and scope of the invention, as defined in the appended claims. For example, the present invention should not be limited by number or coordinates/functions transmitted to the AFES, type of function, type of local computation, means for implementing computation, software/program, computing environment, or specific computing hardware.

CLAIMS

1. A method for assisting a first and second tracking service in anonymizing preference data associated with a first and second user in a phase space, said first and second tracking service tracking preferences of said first and second user respectively, said preference data being defined by one or more parameters, said method comprising the steps of:

a. receiving a request for function evaluation from each tracking service, said request identifying a parameter to be transmitted and a corresponding function to be used for evaluating said identified parameter;

b. transmitting a confirmation to each tracking service indicating transmission of said identified parameter is expected;

c. receiving said identified parameter from each tracking service;

d. evaluating said corresponding function based on said received parameter from each tracking service;

e. transmitting said evaluated result to each tracking service; and wherein steps a through e are repeated for each additional parameter required to define preference data and corresponding function such that each of said service's receives function evaluated results for each parameter separately and utilizes such evaluated results to locally estimate proximity between said first and second user in said phase space without revealing their preference data.

2. A method as per claim 1, wherein communications with said tracking service is done via the hypertext transfer protocol (HTTP).

3. A method as per claims 1 or 2, wherein said parameters are Euclidean coordinates.

4. A method as per claims 1, 2 or 3 wherein said parameters are scalar measures of said preference data.

5. A method in any one of claims 1 to 4, wherein said parameters are vector measures of said preference data.

6. An article of manufacture comprising a computer usable medium having computer readable program code embodied therein for assisting a first and second tracking service in anonymizing preference data associated with a first and second user in a phase space, said first and second tracking service tracking preferences of said first and second user respectively, said preference data being defined by one or more parameters, said method comprising the steps of:

a. computer readable program code aiding in receiving a request for function evaluation from each tracking service, said request identifying a parameter to be transmitted and a corresponding function to be used for evaluating said identified parameter;

b. computer readable program code aiding in transmitting a confirmation to each tracking service indicating transmission of said identified parameter is expected;

c. computer readable program code aiding in receiving said identified parameter from each tracking service;

d. computer readable program code evaluating said corresponding function based on said received parameter from each tracking service;

e. computer readable program code aiding in transmitting said evaluated result to each tracking service; and

wherein computer readable program code of steps a through e are repeated for each additional parameter required to define preference data and corresponding function such that each of said service's receives function evaluated results for each parameter separately and utilizes such evaluated results to locally estimate proximity between said first and second user in said phase space without revealing their preference data.

7. A method for anonymous proximity detection between a first and second mobile user, said first and second mobile users being tracked by a first and second location tracking service (LTS) respectively, said method as implemented by each LTS comprising the steps of:

a. transmitting, to a third party, a first location coordinate along with a corresponding first function to evaluate;

b. receiving a first result from said third party, said first result based upon an evaluation of said first function with said first location coordinate;

c. transmitting, to said third party, a second location coordinate along with a second corresponding function to evaluate;

d. receiving a second result from said third party, said second result based upon an evaluation of second function with said second location coordinate; and

e. computing a measure of distance based upon said received first and second results, said computed distance providing each user with an indication of proximity with respect to the other user.

8. A method as per claim 7, wherein said third party is a non-trusted third party.

9. A method as per claims 7 or 8, wherein communications between said users and said LTS is using the hypertext transfer protocol (HTTP).

10. A method as per claims 7, 8 or 9 wherein said computed distance is measured against a threshold to determine said indication of proximity.

11. A method as in any one of claims 7 to 10, wherein said step of computing distance is implemented locally in a mobile device associated with said mobile users.

12. A method as per claim 11, wherein said distance is computed using a Java Virtual Machine embedded in said mobile device.

13. An anonymous function evaluation service (AFES) comprising:

a. an interface communicating with various tracking services or wireless service providers (WSPs) and receiving parameters and corresponding functions, said parameters associated with one or more users;

b. a task list storing said functions to be evaluated on received data;

c. a data cache storing said received parameters to be processed;

d. a function evaluation engine evaluating mathematical function(s) on parameters; and

e. a task manager operatively linked with said task list, data cache, and function evaluation engine, said task manager: (i) receiving parameters and corresponding functions from said interface; (ii) sending said functions and parameters to task list and data cache respectively; (iii) retrieving said functions from data cache; and (iv) communicating with function evaluation engine and sending results of said function evaluation engine back to said interface for forwarding values to requesting services.

14. An anonymous function evaluation service as per claim 13, wherein said parameters are Euclidian coordinates.

15. An anonymous function evaluation service as per claim 14, wherein said Euclidean coordinates are in a floating point format.

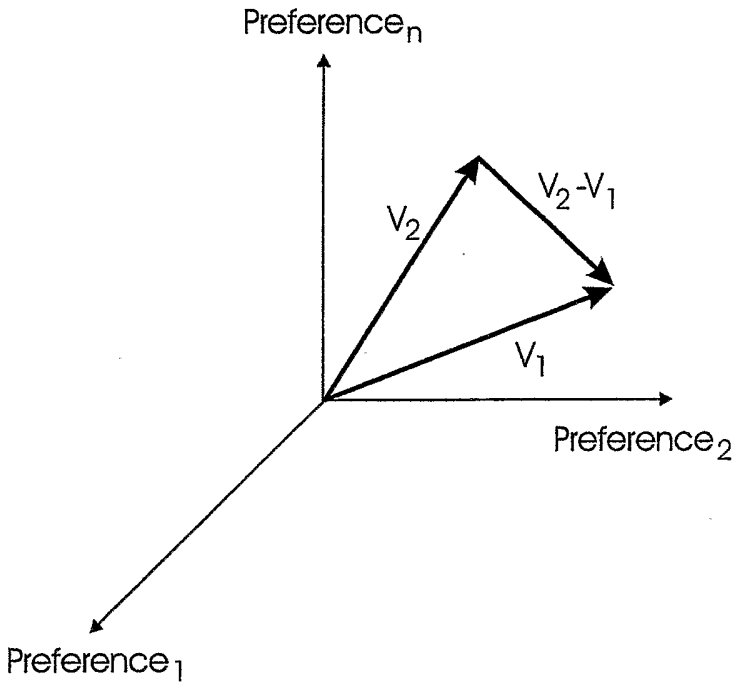
16. An anonymous function evaluation service as per claims 13, 14 or 15 wherein said parameters are scalar measures of preferences associated with users.

17. An anonymous function evaluation service as in any one of claims 13 to 16 wherein said parameters are vector measures of preferences associated with users.

18. An anonymous function evaluation service as in any one of claims 13 to 17, wherein said interface communicates via the hypertext transfer protocol (HTTP).

19. An anonymous function evaluation service as in any one of claims 13 to 18, wherein said AFES is a non-trusted third party.

20. An anonymous function evaluation service as in any one of claims 13 to 19, wherein said task manager performs validity checks on said parameters, evaluation functions, and any identifying keys.



REFERENCED PHASE SPACE

FIG. 1

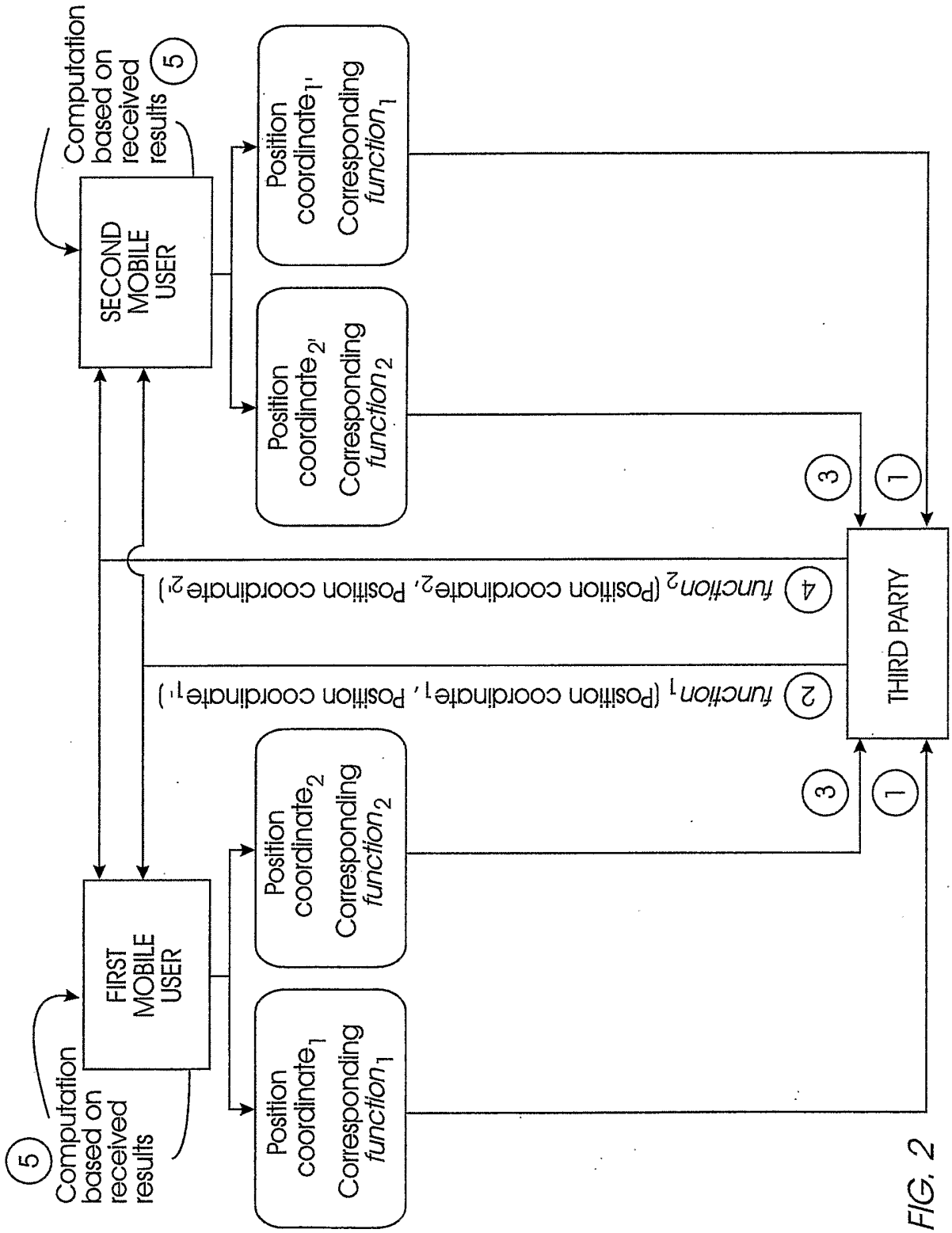

THIRD PARTY
FIRST MOBILE USER
SECOND MOBILE USER
Position coordinate1 Corresponding function1
Position coordinate2 Corresponding function2
Position coordinate1' Corresponding function1
Position coordinate2' Corresponding function2
function1 (Position coordinate1, Position coordinate1')
function2 (Position coordinate2, Position coordinate2')
Computation based on received results
Computation based on received results
1
2
3
4
5
5

FIG. 2

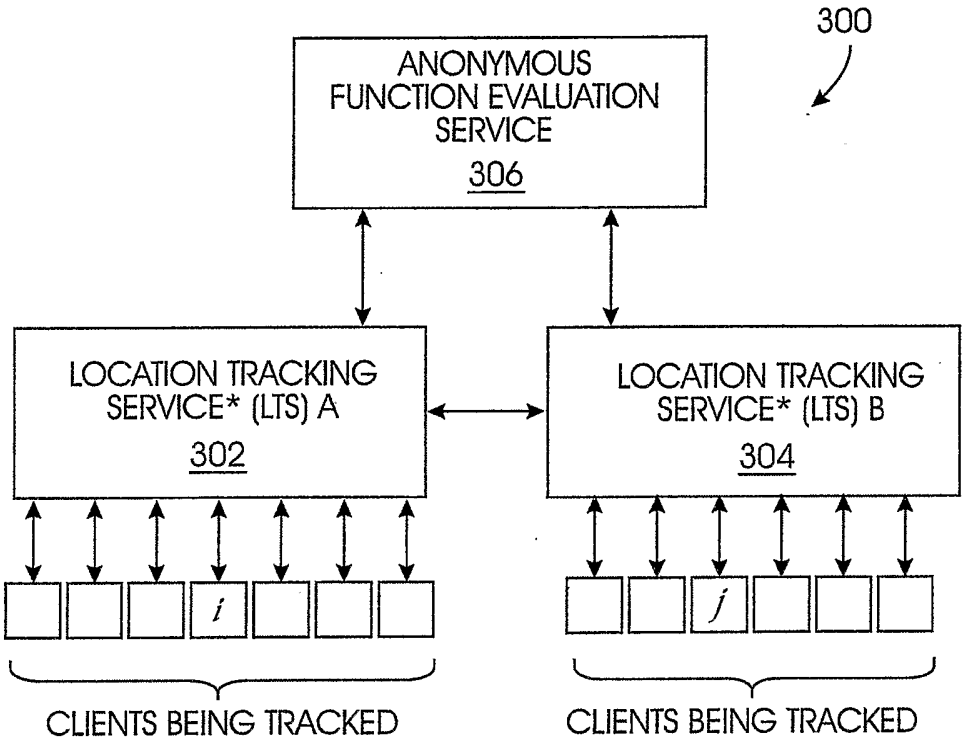

300
ANONYMOUS FUNCTION EVALUATION SERVICE
306
LOCATION TRACKING SERVICE* (LTS) A
302
LOCATION TRACKING SERVICE* (LTS) B
304
i
j
CLIENTS BEING TRACKED
CLIENTS BEING TRACKED

FIG. 3

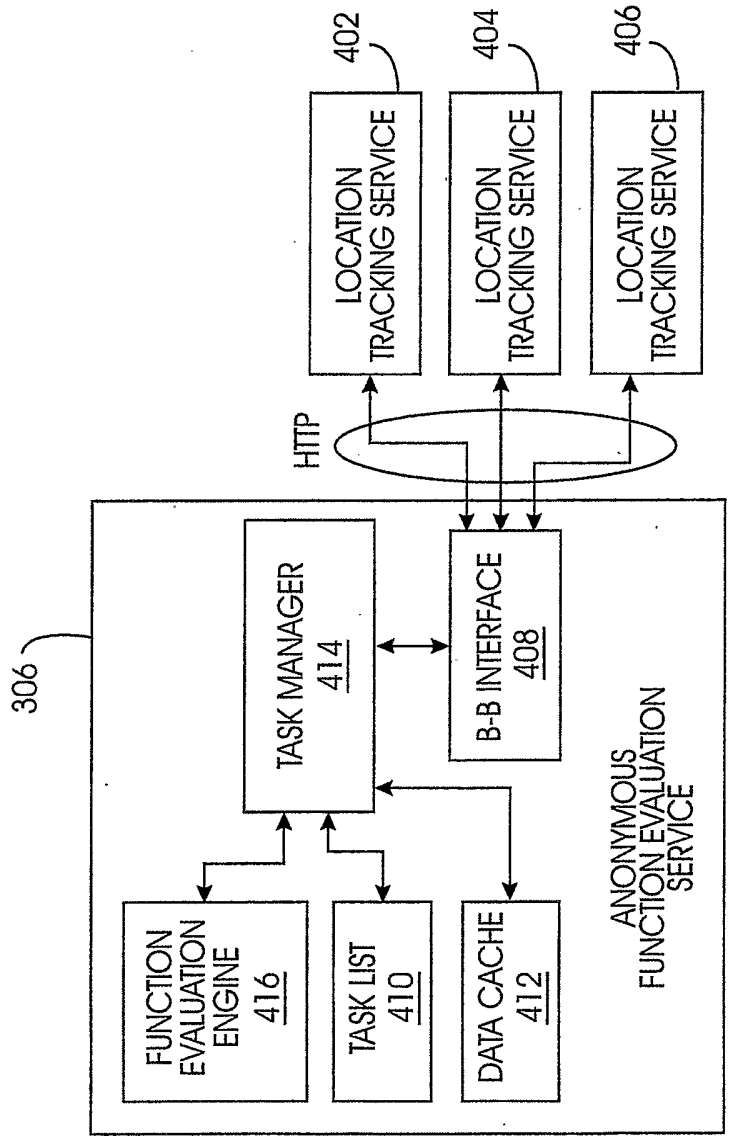

402
404
406
LOCATION TRACKING SERVICE
LOCATION TRACKING SERVICE
LOCATION TRACKING SERVICE
HTTP
306
TASK MANAGER 414
B-B INTERFACE 408
FUNCTION EVALUATION ENGINE 416
TASK LIST 410
DATA CACHE 412
ANONYMOUS FUNCTION EVALUATION SERVICE

FIG. 4

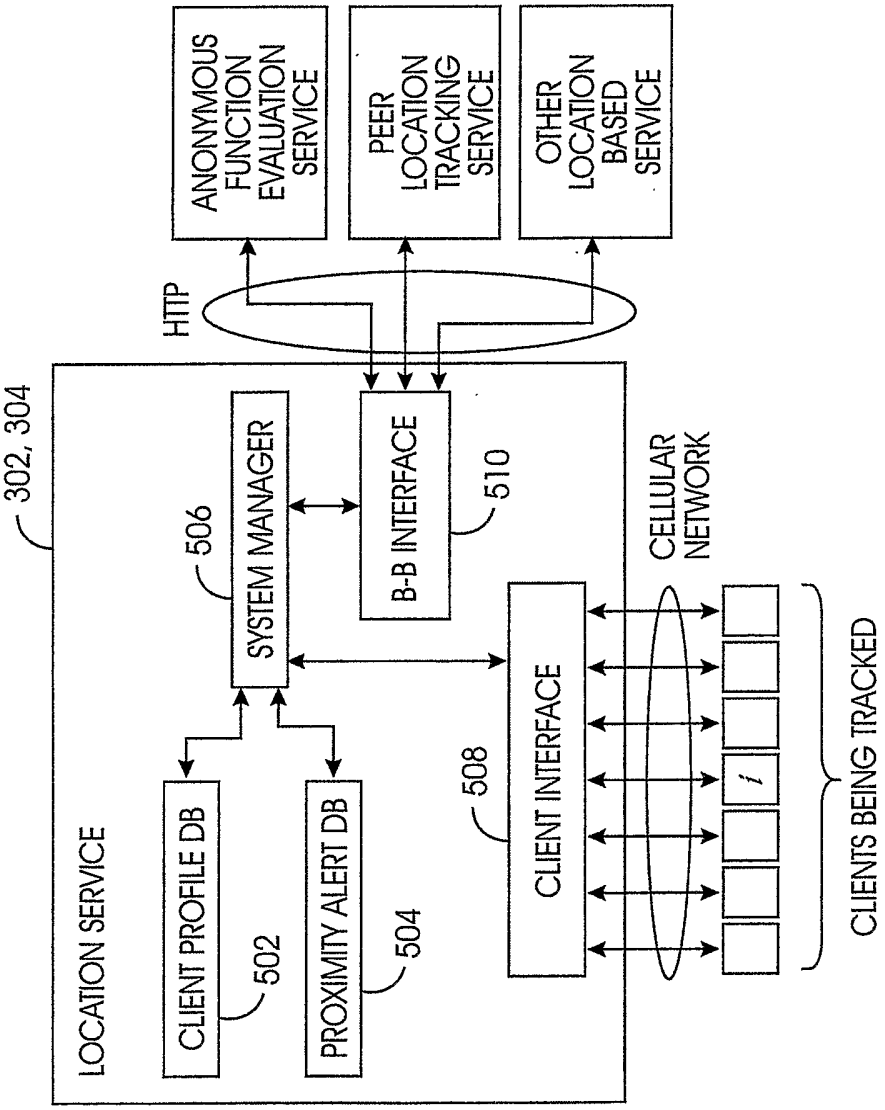

ANONYMOUS FUNCTION EVALUATION SERVICE
PEER LOCATION TRACKING SERVICE
OTHER LOCATION BASED SERVICE
HTTP
302, 304
LOCATION SERVICE
506
SYSTEM MANAGER
B-B INTERFACE
510
CELLULAR NETWORK
CLIENT PROFILE DB
502
PROXIMITY ALERT DB
504
508
CLIENT INTERFACE
CLIENTS BEING TRACKED

FIG. 5

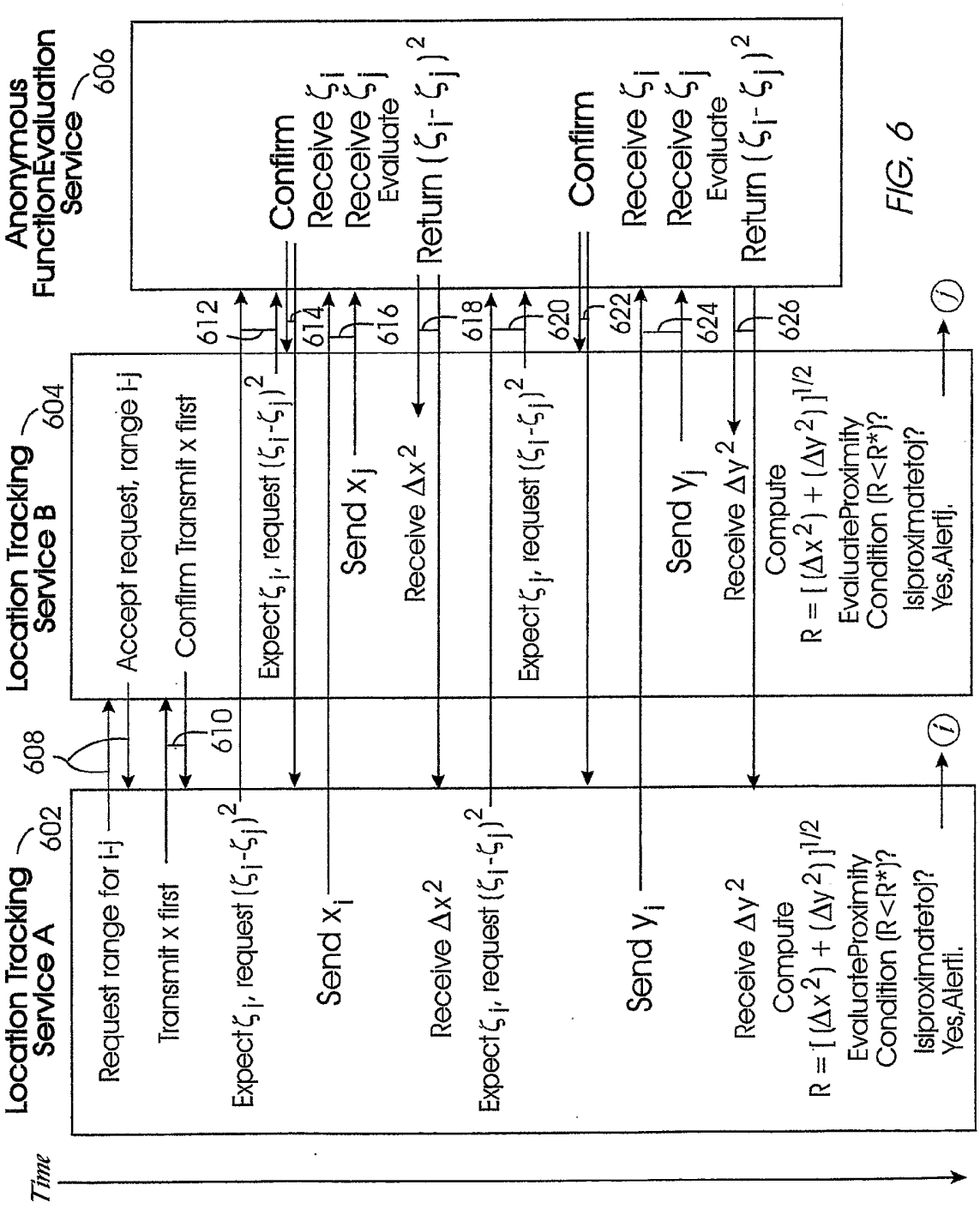

Location Tracking Service A
602
Location Tracking Service B
604
Anonymous FunctionEvaluation Service
606
608
610
612
614
616
618
620
622
624
626
Time
Request range for i-j
Accept request, range i-j
Transmit x first
Confirm Transmit x first
Expect ζ_i, request $(\zeta_i-\zeta_j)^2$
Confirm
Send x_i
Receive ζ_i
Send x_j
Receive ζ_j
Evaluate
Receive Δx^2
Return $(\zeta_i-\zeta_j)^2$
Expect ζ_j, request $(\zeta_i-\zeta_j)^2$
Confirm
Send y_i
Receive ζ_i
Send y_j
Receive ζ_j
Evaluate
Receive Δy^2
Return $(\zeta_i-\zeta_j)^2$
Compute $R = [(\Delta x^2) + (\Delta y^2)]^{1/2}$
EvaluateProximity Condition (R<R*)?
Isiproximatetoj? Yes,Alertj.
Receive Δy^2
Compute $R = [(\Delta x^2) + (\Delta y^2)]^{1/2}$
EvaluateProximity Condition (R<R*)?
Isiproximatetoj? Yes,Alerti.
i
j

FIG. 6

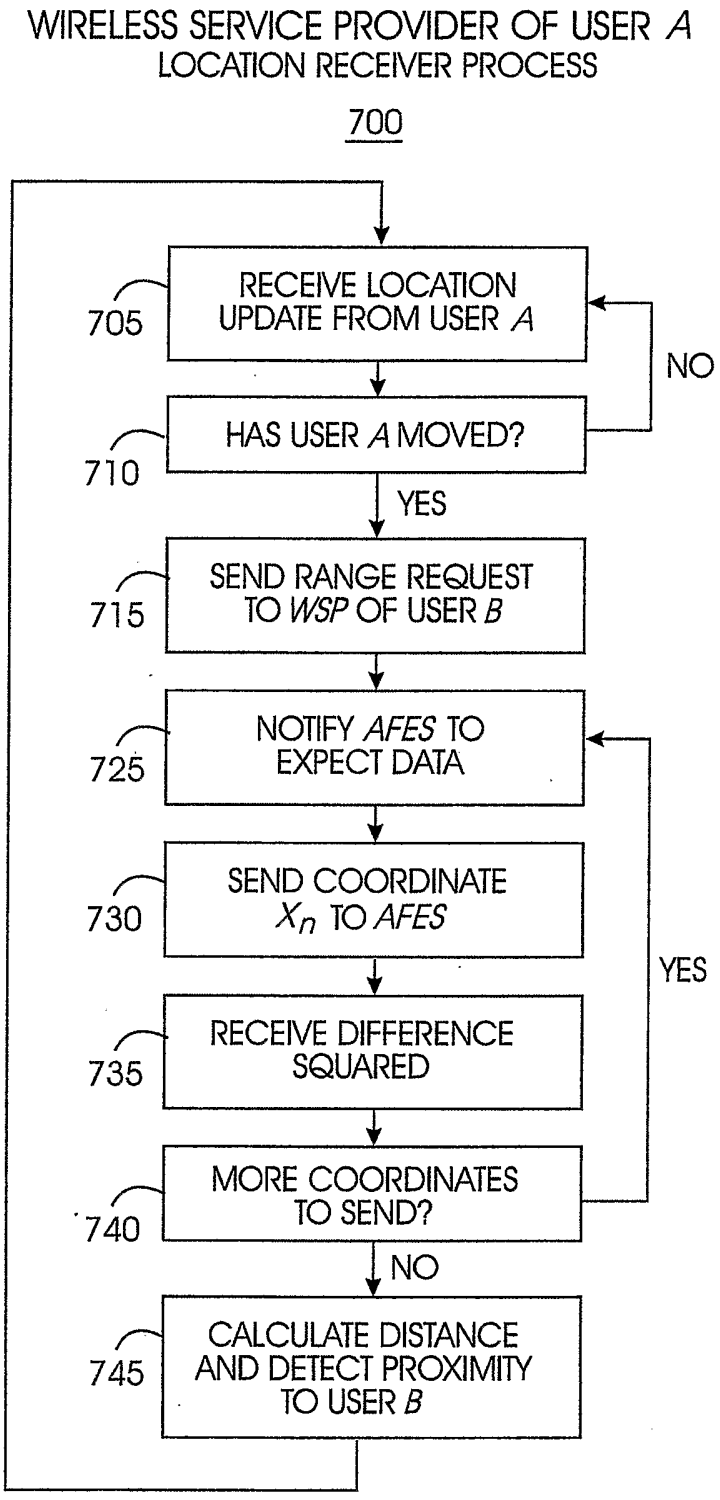

WIRELESS SERVICE PROVIDER OF USER A
LOCATION RECEIVER PROCESS
700
705
RECEIVE LOCATION UPDATE FROM USER A
NO
710
HAS USER A MOVED?
YES
715
SEND RANGE REQUEST TO WSP OF USER B
725
NOTIFY AFES TO EXPECT DATA
730
SEND COORDINATE X_n TO AFES
YES
735
RECEIVE DIFFERENCE SQUARED
740
MORE COORDINATES TO SEND?
NO
745
CALCULATE DISTANCE AND DETECT PROXIMITY TO USER B

FIG. 7

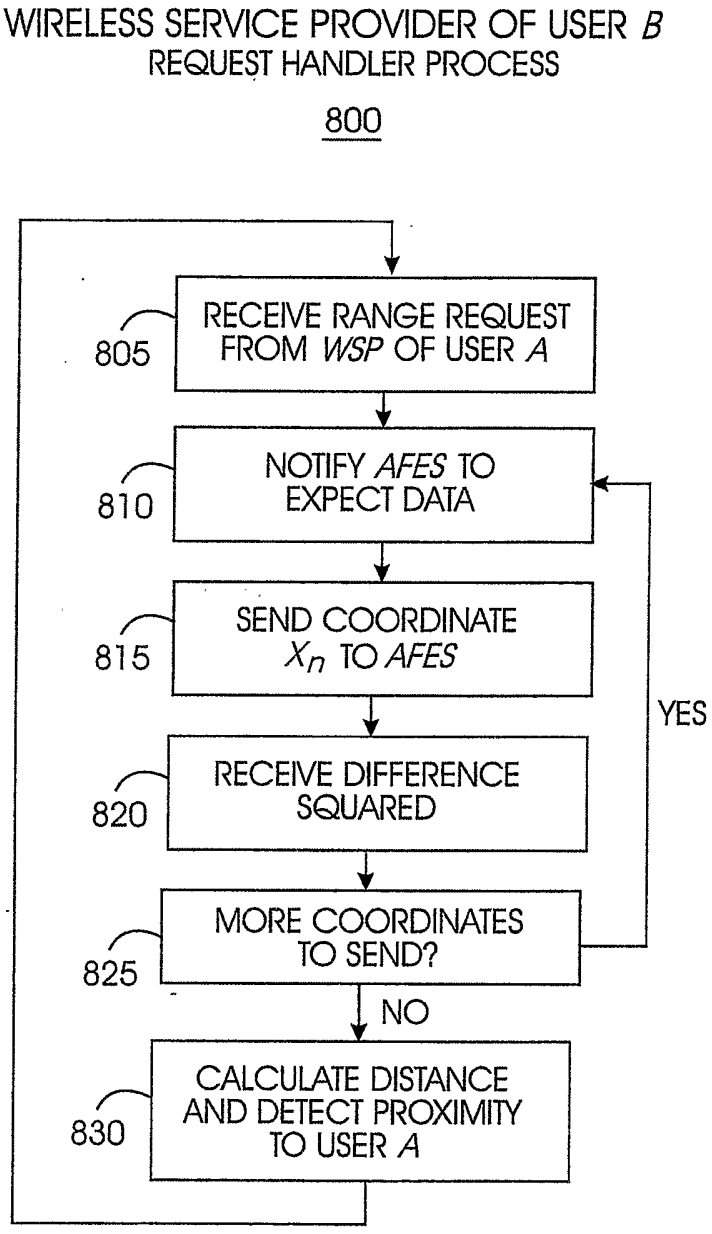

WIRELESS SERVICE PROVIDER OF USER B
REQUEST HANDLER PROCESS
800
RECEIVE RANGE REQUEST FROM WSP OF USER A
805
NOTIFY AFES TO EXPECT DATA
810
SEND COORDINATE X_n TO AFES
815
RECEIVE DIFFERENCE SQUARED
820
MORE COORDINATES TO SEND?
825
YES
NO
CALCULATE DISTANCE AND DETECT PROXIMITY TO USER A
830

FIG. 8

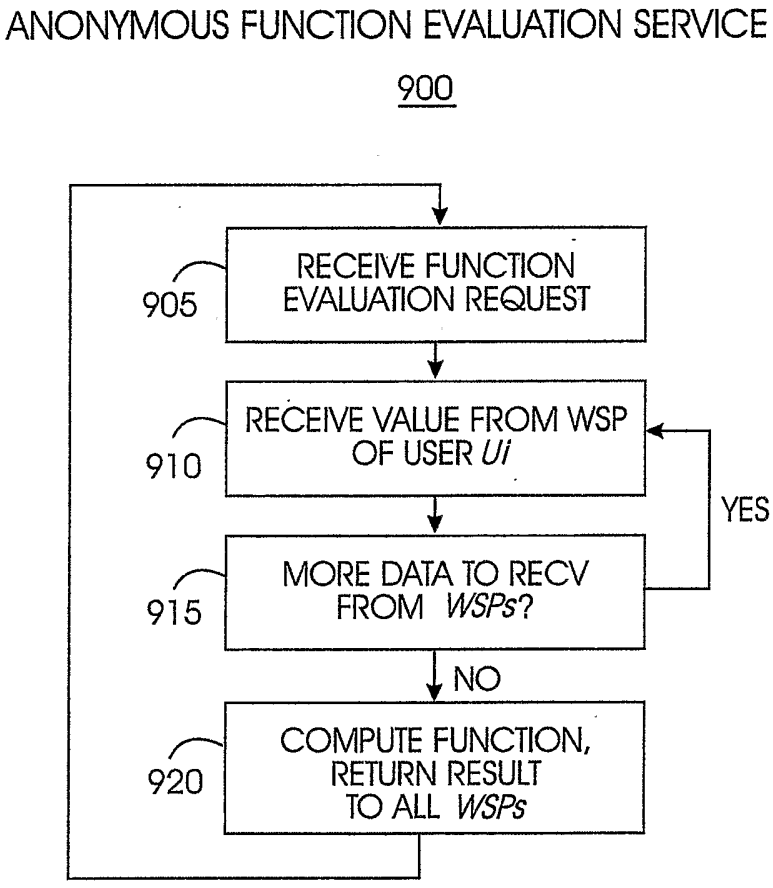

ANONYMOUS FUNCTION EVALUATION SERVICE
900
905
RECEIVE FUNCTION EVALUATION REQUEST
910
RECEIVE VALUE FROM WSP OF USER Ui
915
MORE DATA TO RECV FROM WSPs?
YES
NO
920
COMPUTE FUNCTION, RETURN RESULT TO ALL WSPs

FIG. 9

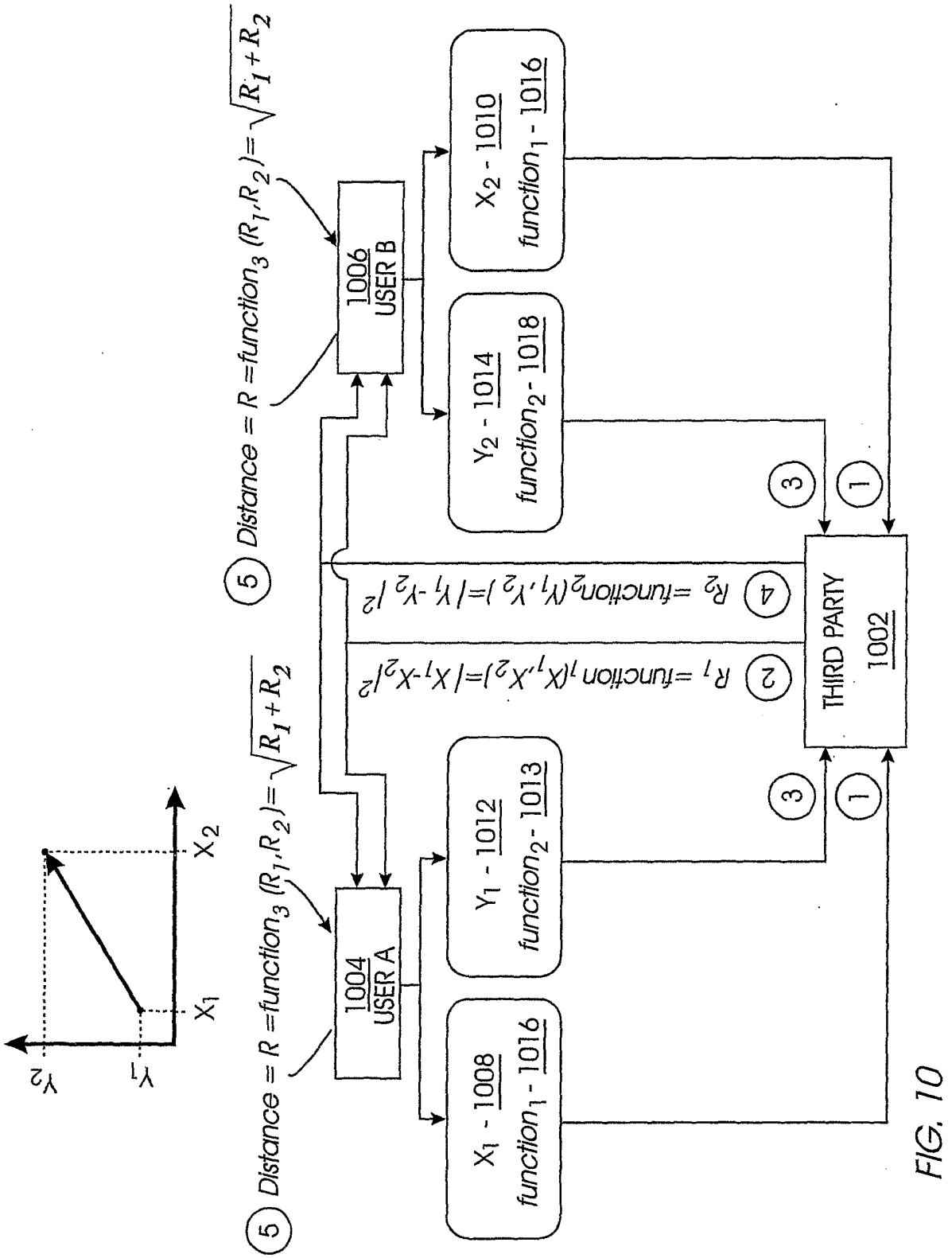

THIRD PARTY
1002
1004
USER A
1006
USER B
X1 - 1008
function1 - 1016
Y1 - 1012
function2 - 1013
X2 - 1010
function1 - 1016
Y2 - 1014
function2 - 1018
R1 =function1(X1,X2)=|X1-X2|2
R2 =function2(Y1,Y2)=|Y1-Y2|2
5 Distance = R =function3 (R1,R2)= √R1+R2
5 Distance = R =function3 (R1,R2)= √R1+R2
X1
X2
Y1
Y2

FIG. 10

INTERNATIONAL SEARCH REPORT

International Application No
PCT/GB 03/04817

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H04M3/42 H04Q7/38

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H04Q H04M H04L G06F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 00/22860 A (DEGNBOL JANUS FRIIS) 20 April 2000 (2000-04-20) page 1, line 5 - line 31 page 2, line 25 - page 3, line 21 page 4, line 1 - page 5, line 24 page 10, line 5 - page 12, line 35 page 13, line 23 - page 15, line 23 page 18, line 27 - page 19, line 12 page 22, line 3 - page 23, line 31 page 24, line 16 - line 22 figures 1,3	1-20
A	US 5 689 809 A (GRUBE GARY W ET AL) 18 November 1997 (1997-11-18) column 2, line 62 - column 3, line 38 abstract; figure 2	1-20

-/--

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

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"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
9 February 2004	23/02/2004

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Bösch, M

Form PCT/ISA/210 (second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

Internatio ...plication No
PCT/GB 03/04817

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
A	WO 01/084867 A (BAIS MICHEL ALEXANDER ; KONINKL KPN NV (NL); SMIRREN DIRK VAN (NL)) 8 November 2001 (2001-11-08) page 1, line 22 - line 30 page 4, line 27 - page 6, line 21 abstract	1-20
A	DE 100 61 993 A (KOMBERG KLAUS ; HAGENSIEKER JENS (DE)) 11 July 2002 (2002-07-11) paragraph '0003! - paragraph '0015! paragraph '0018! abstract	1-20
A	WO 98/48969 A (NIEDERNDORFER FRIEDRICH ; BERGER FRITZ (AT); GRAF STRACHWITZ VON GROSS) 5 November 1998 (1998-11-05) page 13, line 5 - line 34 page 1, line 11 - page 3, line 17 page 8, line 34 - page 11, line 28 page 12, line 12 - line 15 page 14, line 16 - line 21 abstract	1-20
A	DE 100 22 692 A (ZUTHER FRIEDRICH G) 22 November 2001 (2001-11-22) paragraph '0001! paragraph '0005! paragraph '0008! paragraph '0010! - paragraph '0013! paragraph '0016! paragraph '0018! - paragraph '0021! paragraph '0023! abstract	1-20

INTERNATIONAL SEARCH REPORT

Information on patent family members

Internation plication No
PCT/GB 03/04817

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 0022860 A	20-04-2000	AU 6188299 A	01-05-2000
		WO 0022860 A1	20-04-2000
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US 5689809 A	18-11-1997	NONE	
WO 0184867 A	08-11-2001	NL 1015078 C2	05-11-2001
		AU 6592901 A	12-11-2001
		WO 0184867 A1	08-11-2001
DE 10061993 A	11-07-2002	DE 10061993 A1	11-07-2002
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		AU 7012398 A	24-11-1998
DE 10022692 A	22-11-2001	DE 10022692 A1	22-11-2001